



Turbulence Cockpit Displays

NASA Weather Accident Prevention (WxAP) Project Review
September 20-21, 2005

Presented by

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Turbulence Cockpit Displays



Outline:

- Background
- Turbulence System Cockpit Displays Study
- Planned AWIN/TPAWS Integration Experiment (ATIE)
- E-Turb Radar In-Service Evaluation Awareness Display
- Conclusions

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Background : Milestone Definition

- TPAWS Milestone #22 : “Turbulence System Cockpit Displays”
 - Definition : “Develop and demonstrate cockpit displays of turbulence level/warning data.”
 - Exit Criteria : “FAA and industry acceptable cockpit displays of turbulence level/warning data demonstrated.”
- Cockpit Effect Desired.

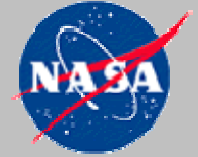
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Background : Flight Data Analysis

- 55 turbulence hazard encounters during FY '02 flight test analyzed to test system performance.
- Display guidelines relative to predicted rms-g load established:
 - < 0.1 rms-g : Must not alert (light)
 - ≥ 0.1 rms-g, < 0.2 rms-g : May alert (moderate)
 - ≥ 0.2 rms-g : Must alert (severe)
- Genesis of idea for two-level display system.

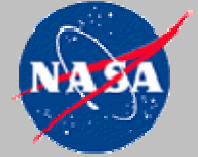
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Turbulence Systems Display Study

- Performed by Dr. George Boucek of Research Triangle Institute (RTI) in 3rd and 4th Quarter of FY '03.
- Task Definition:
 - “The contractor shall identify operational requirements for an airborne-radar-based, turbulence alerting system. The candidate concepts identified shall be for a “Near-term Alerting System” that capitalizes on recent improvements in the performance of airborne weather radars in detecting turbulence within 120 seconds of the aircraft.”

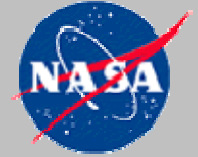
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Turbulence Systems Display Study : Design concepts

- Developed two display system concepts that can be used together or separately.
 - Alerting concept that detects with a high accuracy a moderate and/or severe turbulence event that the aircraft will penetrate within 120 seconds and informs the flight crew using aural and visual alerts.
 - Awareness concept that provides the flight crew with turbulence awareness both on and off the flight path and at a greater distance than the alerting system.

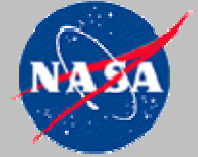
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Turbulence Systems Display Study : Alerting Concept

- Excerpt of Alerting Concept Requirements:
 - Develop an economically viable implementation.
 - Alerts must be integrated and prioritized with other non-normal alerts (e.g. TAWS).
 - The system should be optional – no mandate, no MEL impact.
 - No requirement for interface with master alerts, EICAS/ECAM, or flight data recorder.

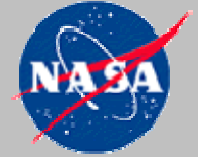
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Turbulence Systems Display Study : Alerting Concept

- Excerpt of Alerting Concept Requirements (cont.):
 - Turbulence Alert should be treated as ALERT only.
 - “No Alert” does not mean that there is no turbulence, and an on-path alert does not mean there is no off path turbulence.
 - An avoidance maneuver based on radar turbulence alert may lead into undetected/undisplayed turbulence.

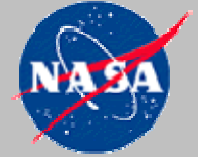
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Turbulence Systems Display Study : Alerting Concept

- Excerpt of Alerting Concept Requirements (cont.):
 - Acceptable levels for false, nuisance, and missed alerts must be defined.
 - What causes a false/nuisance/missed alert?
 - What are the consequences of a false/nuisance/missed alert (e.g. flight crew and passenger confidence)?
 - The answers will drive system requirements and intended function.

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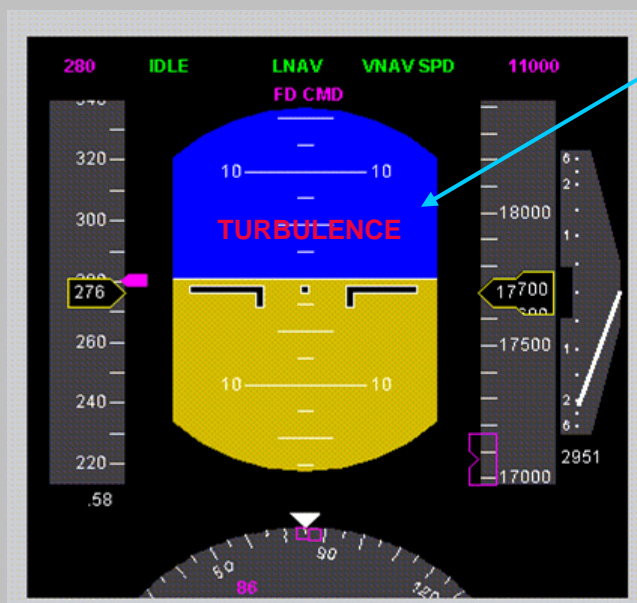
Turbulence Systems Display Study : Alerting Concept

- Excerpt of Alerting Concept Requirements (cont.):
 - Separate short range and long range systems.
 - Establish possibly different alerting criteria for short and long range systems.
 - Initially focus on the “short range – sit down and hang on” system.
 - Both visual and aural annunciation required for alerting.



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Turbulence Systems Display Study : Alerting Concept



Alerting Components



Warning Sound
plus
"Warning Turbulence,
Warning Turbulence"



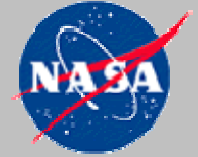
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Turbulence Systems Display Study : Awareness Concept

- Excerpt of Awareness Concept Requirements:
 - Develop an economically viable implementation.
 - The system should be optional – no mandate, no MEL impact.
 - Two-Level system to indicate separate areas of moderate turbulence and severe turbulence.

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Turbulence Systems Display Study : Awareness Concept

- Excerpt of Awareness Concept Requirements (cont.):
 - Identify the location of ownship.
 - Provide the intended flight path.
 - Provide location of significant turbulence relative to ownship and the intended flight path.

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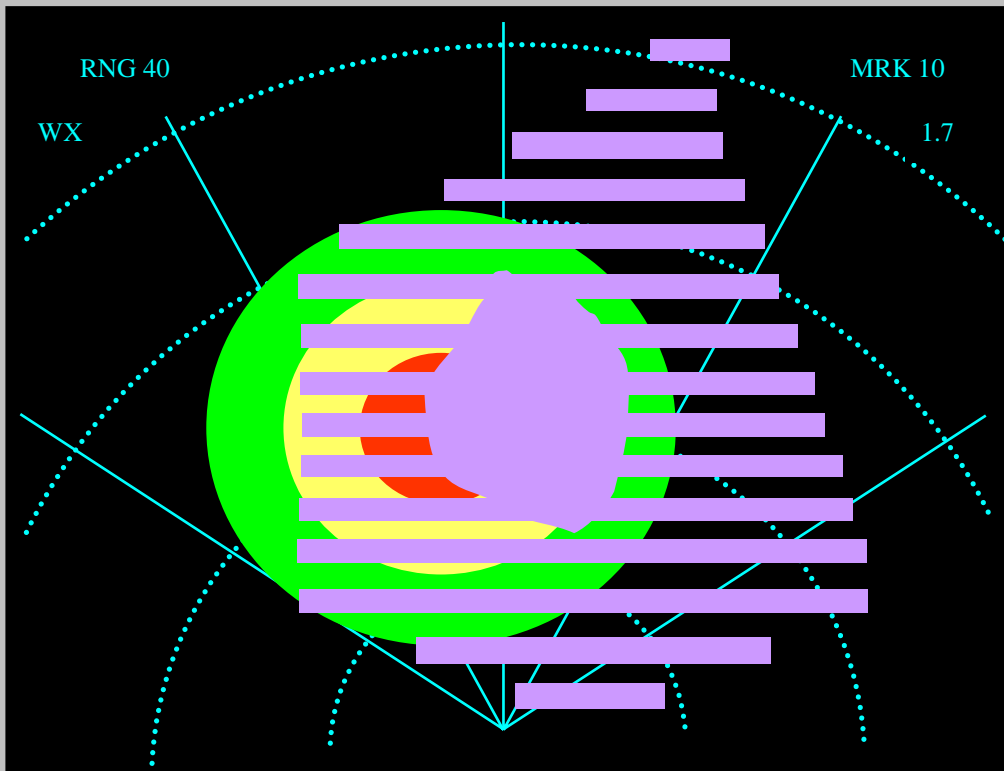
Turbulence Systems Display Study : Awareness Concept

- Excerpt of Awareness Concept Requirements for Awareness Display Integrated with Alerting Concept:
 - Indicate any turbulence causing non-normal alerts.
 - Indicate urgency level of any alerts.
 - Provide an indication of the alert swath around the intended flight path.

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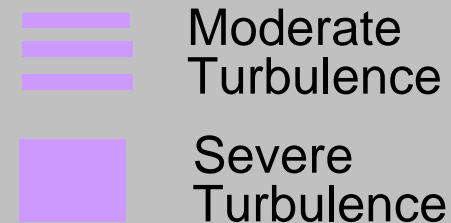


Turbulence Systems Display Study : Awareness Concept



Turbulence Icon Concept:

- Turbulence regions processed
- Icons assigned



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Turbulence Systems Display Study : Awareness Concept



Turbulence Bin Concept:

- Turbulence regions not processed
- Individual display bin fill amount based on predicted turbulence severity

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Turbulence Systems Display Study : Research Basis

- General industry acceptance of awareness display concept.
- Additional cost of fully implemented alerting concept may make system undesirable.
- Simulation needed to assess benefits of alerting concept.
- AWIN/TPAWS Integrated Experiment (ATIE) designed to address alerting versus awareness-only trade-offs.

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AWIN/TPAWS Integrated Experiment (ATIE)

- Turbulence aspect of AWIN/TPAWS Integrated Experiment (ATIE) design based on recommendations and results of Turbulence System Display Study.
- ATIE hypotheses developed to address issues of the integration of the two systems, issues relative to AWIN only, and issues relative to TPAWS only.
- ATIE integrated hypothesis:
 - “The addition of strategic weather information through the use of AWIN system will increase crew preparedness to turbulence events.”

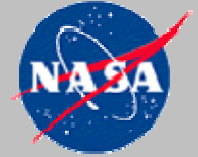
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AWIN/TPAWS Integrated Experiment (ATIE)

- ATIE TPAWS hypotheses:
 - “Turbulence awareness display will increase crew preparedness for turbulence encounters.”
 - “The addition of the turbulence alerting system will result in fewer unprepared for turbulence encounters.”
- Primary TPAWS purpose: The evaluation of the effectiveness of alerting+awareness display concept versus the awareness only display concept.

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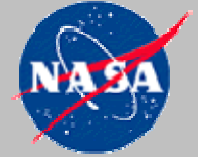
AWIN/TPAWS Integrated Experiment (ATIE) : Experimental Design

	TPAWS AWARENES S	TPAWS ALERTING
NO AHAS	1	4
AHAS WITHOUT DECISION AIDS	2	5
AHAS WITH DECISION AIDS	3	6

- Incomplete Factorial with Control
- Advantage is allowance for a baseline control group.
- Completely Within-Subjects
- Crews not run in same order

Control: No
TPAWS or
AHAS
systems
(7)

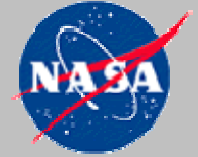
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AWIN/TPAWS Integrated Experiment (ATIE) : Approach

- Piloted Evaluations
- Flight Scenarios
 - Daytime flights.
 - Enroute commercial line flight.
 - Each collection scenario to run 30 minutes.
 - Initialized at cruise altitude (all flights > FL 180).
 - Flights will be approaching convective activity.
 - Total of 7 research flights.
 - Workload and situational awareness measures will be taken following each experimental run.

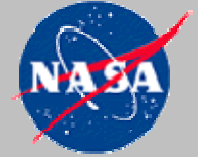
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AWIN/TPAWS Integrated Experiment (ATIE) : Approach

- Three Weather Scenarios
 - Burlington to Covington
 - Nashville to Norfolk
 - Indianapolis to Norfolk
- Six Factorial Display Conditions plus Control (7 Total)
- Twelve Crews
- Each crew will see each of the seven factorial display conditions and the control condition once.
- Each crew will see two weather scenarios twice and one weather scenario three times.

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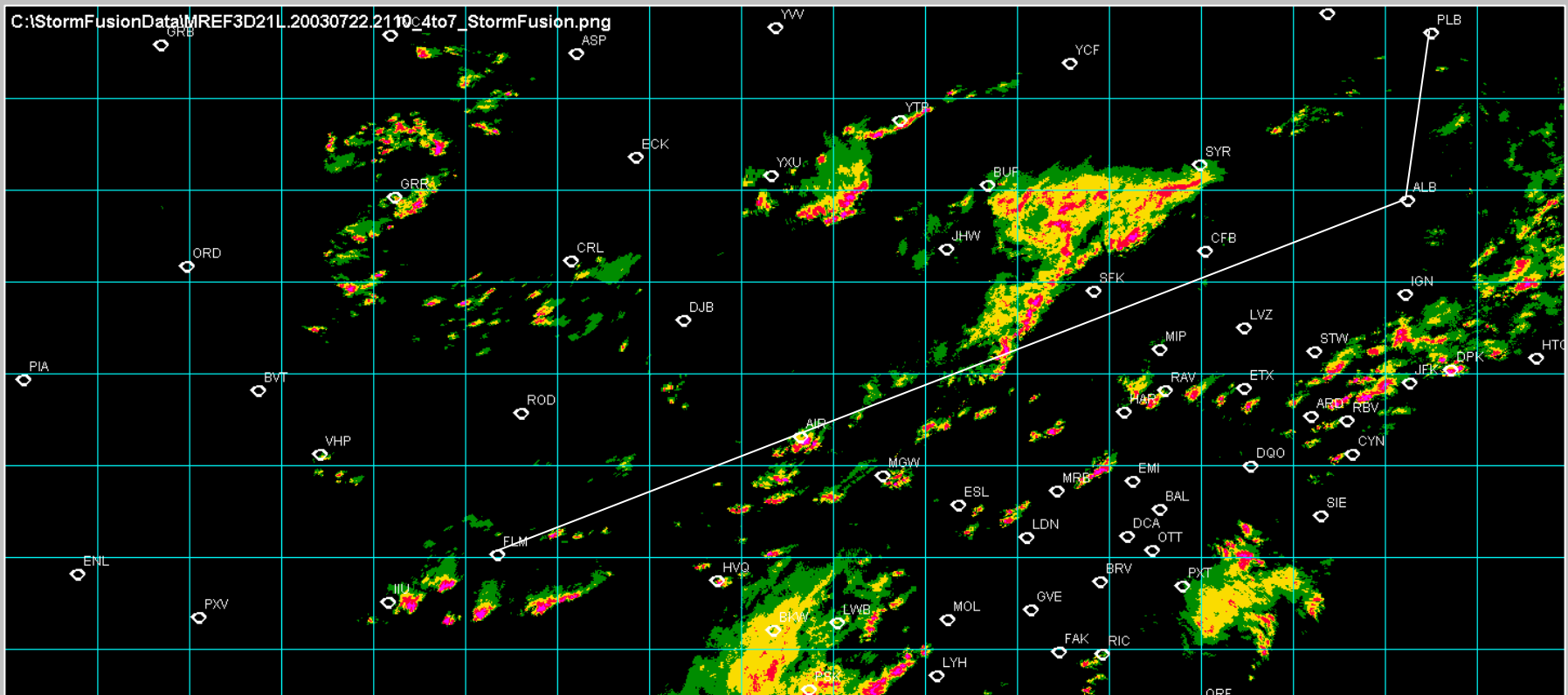
AWIN/TPAWS Integrated Experiment (ATIE) : Scenarios

- Flight scenarios were developed using historical weather data.
- Selected one weather day from database with high degree of convective activity and built flight scenarios around that day.
- Weather data available from Rockwell ground station archive allowing for AHAS full functionality.
- Worked with industry pilots to establish scenarios.

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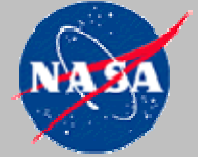
AWIN/TPAWS Integrated Experiment (ATIE) : Example Scenario



Burlington, VT to Covington, KY

Explore. Discover. Understand.

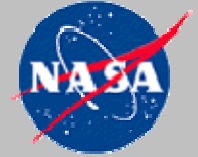
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AWIN/TPAWS Integrated Experiment (ATIE) : Data

- Pilot Workload – NASA TLX
- Situational Awareness - SART
- Pilot Questionnaires (Pre- and Post-Flight)
 - Pre-flight questionnaire to assess airline policies and weather experience.
 - Post-flight questionnaire to address weather information, display issues and questions related to preferred weather displays and turbulence systems.
- Video Recording of Crew

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AWIN/TPAWS Integrated Experiment (ATIE) : Facilities



NASA Ames
Crew Vehicle
Systems
Research
Facility
747-400

Explore. Discover. Understand.

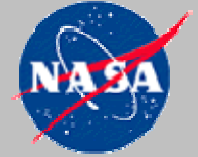
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AWIN/TPAWS Integrated Experiment (ATIE) : Facilities

- NASA Ames Crew Vehicle Systems Research Facility 747-400
 - Programmable flight displays
 - Six degree-of-freedom motion system
 - Sound and aural cues
 - Weather radar system simulation
 - High-fidelity visual system
 - ARINC 429 and 453

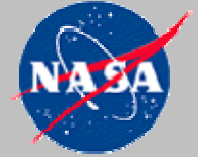
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AWIN/TPAWS Integrated Experiment (ATIE) : Fate

- Budgetary problems delayed deployment of funds.
- Personnel upheavals delayed technical data interchange.
- NASA agency level refocus reduced Ames simulation personnel, increasing experiment implementation time.
- Combination of delays pushed simulation start past the completion of the WxAP program.
- Simulation Canceled

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E-Turb Radar In-Service Evaluation Display

- Two-Level Awareness Display
- No Alerting System (Awareness Only)
- Turbulence Bin Concept. Does not process “areas” of turbulence.
- Displays light-to-moderate turbulence with dot pattern.
- Displays moderate-to-sever turbulence with solid pattern.

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E-Turb Radar In-Service Evaluation Display



- Magenta colored used to display turbulence.
- Light-to-Moderate fill dot coverage about 16%.
- Turbulence displayed within ~25 NM of aircraft, independent of current selected weather scale.
- Easy pilot training.

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E-Turb Radar In-Service Evaluation Display

- Evaluated by airline pilots during revenue runs (real weather, real situations).
- Two-Level awareness display seen as a large improvement over previous turbulence presentations (single level). Allows for better tactical decisions.
- Five months worth of data collection provided a large data set from which further research into display improvements may be derived.

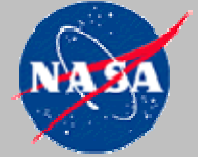
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Conclusions : Part 1

- Strong industry and FAA support for two-level turbulence awareness displays.
- Two-Level awareness display concept allows for strategic and tactical flight path decisions for increased passenger safety and comfort, and for enhanced flight operations and fuel efficiency.
- Preliminary indications from the in-service evaluation of the two-level awareness display concept are that the display is conspicuous enough that an alerting system may not be needed.

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Conclusions : Part 2

- Turbulence alerting displays need additional research to determine effectiveness.
- Further research into the presentation other types of turbulence information (TAPS, etc.)

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Comments and Questions